

Curvature–Memory Channels Across Interface Horizons

A Theoretical Construction Derived from the Horizons-as-Dimensional-Interface Framework (HDIF)

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Abstract

We explore a class of geometric configurations within the Horizons-as-Dimensional-Interface Framework (HDIF) in which curvature and memory terms co-align to form stable, directional channels across interface horizons. These structures—which we refer to as *curvature–memory channels*—arise not as engineered devices, but as mathematically defined boundary solutions to HDIF’s interface field equations. The resulting channels provide a controlled route through which curvature imbalance and memory-weighted propagation can couple across adjacent horizon regions. This paper presents their derivation, stability properties, and physical interpretation, while avoiding speculative technological claims.

1 Introduction

HDIF models spacetime as a network of interacting interface horizons whose geometry is governed by curvature–memory coupling. In this framework, classical curvature, quantum fluctuations, and nonlocal memory terms coexist as components of a unified interface field. Certain boundary configurations lead naturally to the emergence of one-dimensional directional structures: pathways through which the curvature–memory imbalance propagates in a controlled manner. These structures form the focus of this work.

Rather than interpreting such pathways as portals, devices, or engineered mechanisms, we treat them as *mathematically defined field channels*. This perspective allows us to analyze their existence, behavior, and limits using only the internal logic of HDIF and established differential geometry.

2 Background: Interface Horizons and Memory Weighting

In HDIF, each interface horizon is characterized by a metric $g_{\mu\nu}$, a baseline curvature offset Λ_0 , and a memory kernel $M_{\mu\nu}(\tau)$ describing nonlocal response. In the notation of the main HDIF framework [1], the interface field equation (HDIF Eq. 24) can be rewritten schematically as

$$\bar{C}_{\mu\nu} + \Lambda_0 g_{\mu\nu} = \alpha M_{\mu\nu}(\tau) + \mathcal{F}_{\mu\nu}$$

where $\bar{C}_{\mu\nu}$ denotes the combined curvature contributions (HDIF terms $G_{\mu\nu} + C_{\mu\nu}$ in Eq. 24). For the purposes of this paper, we focus on the competition between the memory term $M_{\mu\nu}$ and the curvature term $\bar{C}_{\mu\nu}$.

The interplay between curvature contributions and memory weighting, governed by the dimensionless parameter α , determines whether a region behaves as:

- curvature-dominant
- memory-dominant
- or in a transitional regime where neither term vanishes

Curvature–memory channels occur specifically in this transitional regime.

3 Definition of Curvature–Memory Channels

3.1 Motivation

A curvature–memory channel is defined as a region of the interface where the directional derivative of $\mathcal{C}_{\mu\nu}$ and that of $M_{\mu\nu}(\tau)$ align:

$$\nabla_{\mathbf{u}} \mathcal{C}_{\mu\nu} \propto \nabla_{\mathbf{u}} M_{\mu\nu}(\tau) \tag{1}$$

with $\mathbf{u}$ a timelike or null tangent along the channel.

This alignment ensures that curvature and memory reinforce rather than oppose each other, generating a quasi-stable propagation corridor.

3.2 Existence Conditions

Channels exist only when three conditions are simultaneously satisfied:

1. **Directional alignment:** $\nabla_{\mathbf{u}} \bar{C}_{\mu\nu} \propto \nabla_{\mathbf{u}} M_{\mu\nu}(\tau)$
2. **Imbalance gradient:** $\mathbf{u}^\mu \partial_\mu \Delta\Phi > 0$
3. **Tangency constraint:** $\partial_\perp \Delta\Phi|_{\text{horizon}} = 0$

Generic interface geometries do not satisfy these relations; channels represent special, fine-tuned boundary solutions rather than generic features of HDIF horizons.

4 Mathematical Structure

Let I denote an interface horizon with local coordinates x^μ . Define the curvature–memory imbalance scalar

$$\Delta\Phi = \text{Tr}(\mathcal{C}_{\mu\nu}) - \alpha \text{Tr}(M_{\mu\nu}) \quad (2)$$

A channel forms where $\Delta\Phi$ exhibits a monotonic directional gradient:

$$\mathbf{u}^\mu \partial_\mu \Delta\Phi > 0 \quad (3)$$

This indicates a unidirectional flow of curvature–memory interaction energy across the horizon. The boundary condition supporting such flow is described by the constraint:

$$\partial_\perp \Delta\Phi|_{\text{horizon}} = 0 \quad (4)$$

ensuring that the channel remains tangent to the interface rather than escaping orthogonally.

5 Phase-Space Behavior

Channels occupy specific regions of $(\Delta\Phi, \alpha)$ phase space, typically near the transitional boundary between curvature- and memory-dominated regimes. The channel’s stability depends on:

- sign and magnitude of $\partial_{\mathbf{u}} \Delta\Phi$
- the memory timescale encoded in $M_{\mu\nu}(\tau)$
- local curvature eigenvalues of $\mathcal{C}_{\mu\nu}$

6 Physical Interpretation

Although the term “channel” may evoke notions of transport or passage, we emphasize that the structure is purely geometric. No physical object or signal travels “through” the channel beyond what HDIF already allows via curvature–memory propagation.

These channels are analogous to:

- geodesic congruences in GR
- preferred flow lines in fluid dynamics
- renormalization trajectories in QFT

They represent *preferred directions* in the combined curvature–memory landscape.

7 Limitations

The existence and stability of channels rely on:

- validity of the HDIF field equation
- smoothness assumptions on $M_{\mu\nu}(\tau)$
- absence of strong discontinuities in horizon geometry

Further, channels do not constitute portals, devices, or engineered mechanisms.

8 Conclusion

Curvature–memory channels emerge as natural boundary solutions of HDIF interface dynamics. They occupy a well-defined region of phase space, exhibit directional propagation, and provide insight into how curvature and memory may interact across contiguous horizon regions. Future work will involve numerical modeling, analytic classification, and investigation of their role in HDIF’s global structure.

References

- [1] C. Zeitz, *Horizons-as-Dimensional-Interface Framework: A Falsifiable Unification of General Relativity and Quantum Field Theory via Curvature–Coupled Fields*, Zenodo preprint (2025), doi:10.5281/zenodo.17850602.

Appendix — Early Toy Model: Interface–Annulus Geometry

Context. The material in this appendix is retained from early exploratory work carried out during the initial development of HDIF. It represents a simplified, pedagogical toy model used to visualize interface layering, angular partitioning, and probabilistic exclusion by obstacles. Although this model played an important role in motivating later formal developments, it is *not part of the HDIF Core field equations* and should not be interpreted as a physical representation of interface horizons. Its purpose here is strictly historical and illustrative.

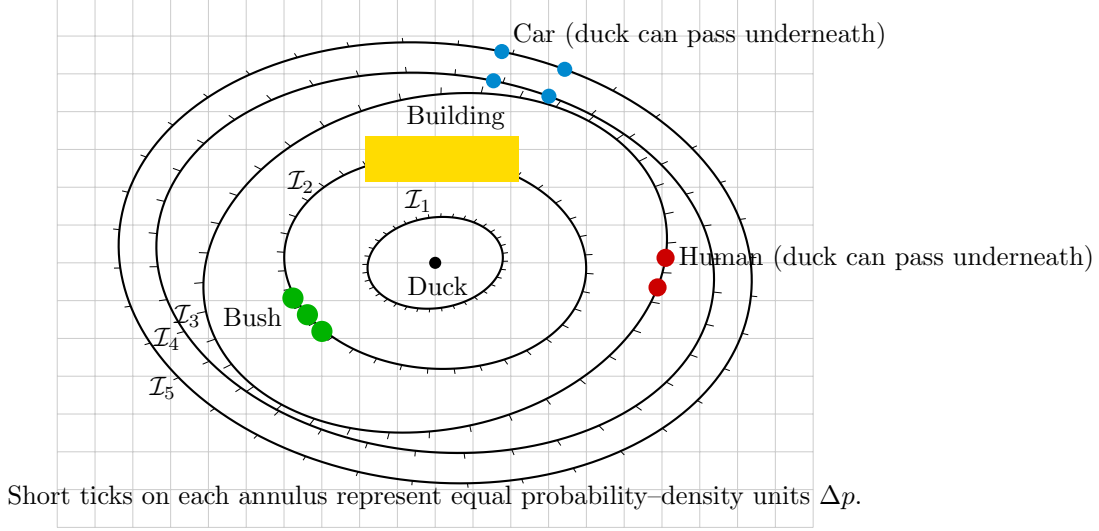


Figure 1: **Early toy model (historical).** A schematic annulus-based probability model developed during the initial phase of HDIF exploration. Concentric, asymmetric annuli represent interface-like layers; tick marks encode discrete probability units; and simple obstacles (building, human, bush, car) modify sector weights. This diagram is not part of the formal HDIF geometry, but illustrates early intuition about how local structure, angular partitioning, and partial permeability can be encoded in a simplified interface model.

Mathematical Description (Toy Model)

This toy model provides a clean mathematical abstraction of the diagram above. It is intentionally simple and predates the current curvature-memory formalism. It is included for pedagogical completeness only.

Let the background grid represent a flat spacetime manifold

$$\mathcal{M} \simeq \mathbb{R}^2$$

A point particle (located at the origin in the diagram) sits at position $x \in \mathcal{M}$. Concentric “interface-annuli” are defined by

$$\mathcal{I}_k = \{x \in \mathcal{M} \mid \|x\| = r_k\} \quad 0 < r_1 < r_2 < r_3 < r_4$$

Each annulus $\mathcal{I}_k$ is partitioned into N_k equal angular sectors,

$$\mathcal{I}_k = \bigsqcup_{j=1}^{N_k} S_{k,j}$$

and each sector corresponds to one unit of discrete probability

$$\mathbb{P}(x \in S_{k,j} \mid x \in \mathcal{I}_k) = \frac{1}{N_k}$$

Obstacles

$$\mathcal{O}_\alpha \subset \mathcal{M}$$

remove or modify sectors. For a fully blocking obstacle,

$$\mathbb{P}(x \in S_{k,j} \cap \mathcal{O}_\alpha) = 0$$

while partially permeable obstacles (such as the “human legs” or “car tires” in the original drawing) define narrow allowed channels $C_\alpha \subset \mathcal{O}_\alpha$ with

$$\mathbb{P}(x \in C_\alpha) > 0$$

The toy model can therefore be summarized as the triple

$$(\mathcal{M}, \{\mathcal{I}_k\}_{k=1}^4, \{\mathcal{O}_\alpha\})$$

equipped with a discrete probability measure on angular sectors, modified by the exclusion or partial-transmission rules imposed by obstacles.

Note. This model served as a precursor to the modern HDIF treatment of horizon geometry, but does not represent or approximate HDIF in its present theoretical form.